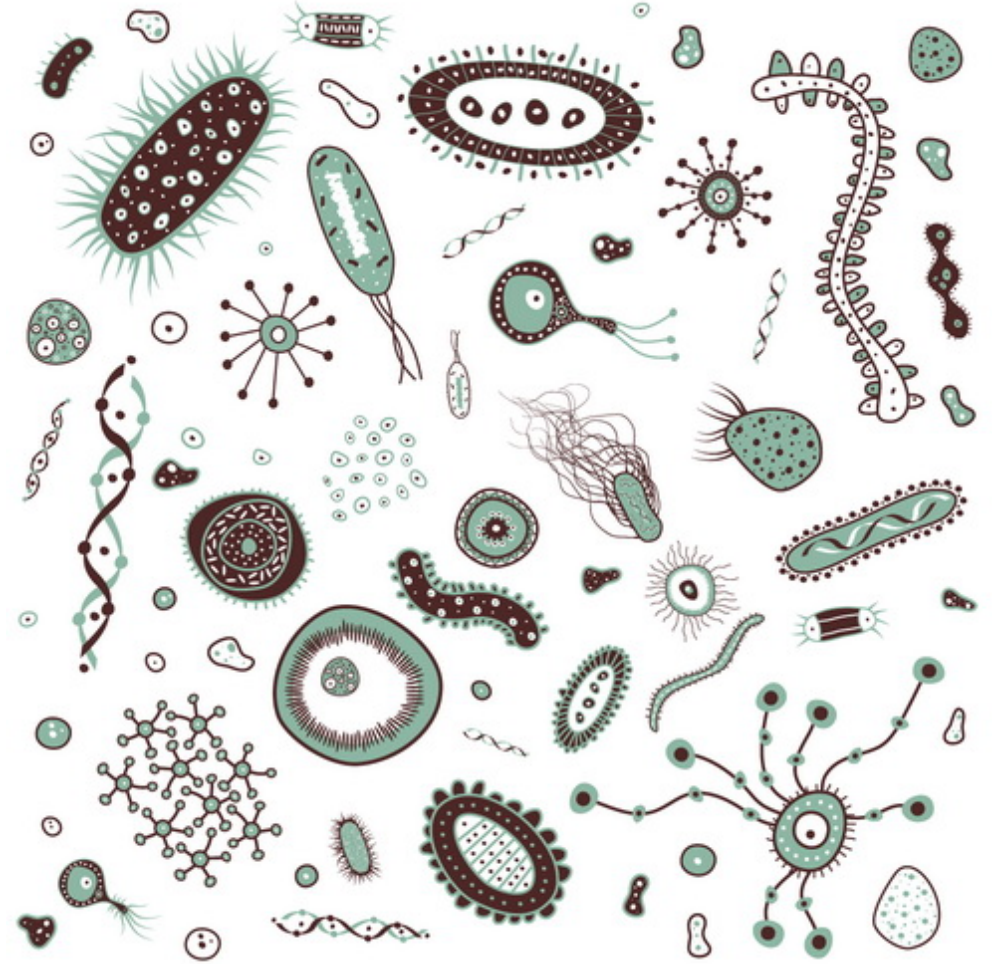


# Parasites and pathogens and some of their roles in the ecology of Lepidoptera



Toby Hammer  
University of Colorado Boulder

# Themes

1) Microbes can sometimes explain puzzling phenomena, like

- Weird sex ratios
- Population cycles
- Oviposition preferences and other behaviors
- Caterpillar melting, glowing, and smells

2) Lep parasites and pathogens are diverse and interesting!

# Outline

- a) A bit of history: Pasteur and silkworm disease
- b) Bacteria: *Wolbachia*, a common reproductive parasite
- c) Viruses: baculoviruses and gypsy moths
- d) Protozoa: *Ophryocystis elektroscirrha* and monarchs
- e) Fungi: *Ophiocordyceps* and himalayan hepialid larvae
- f) Nematodes that attack caterpillars
  
- g) Gut microbiomes in Lepidoptera

# Pasteur and silkworm disease



Different microorganisms  
cause different diseases, and  
require different treatments



“Pebrine” (microsporidian)



“Flacherie” (bacteria and/or virus)

# *Wolbachia* and sex ratios



*Hypolimnastis bolina* male

1920's: entomologists on Fiji and Samoa observe extremely female-biased sex ratios

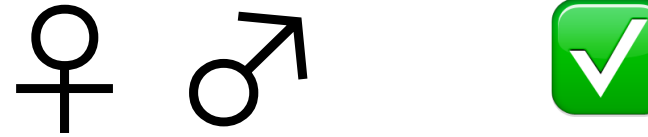
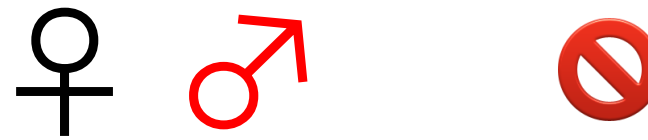
90% of females lay broods in which half the eggs never hatch; surviving offspring all female



*Wolbachia* selectively kills male embryos

Charlat et al. Science 2006

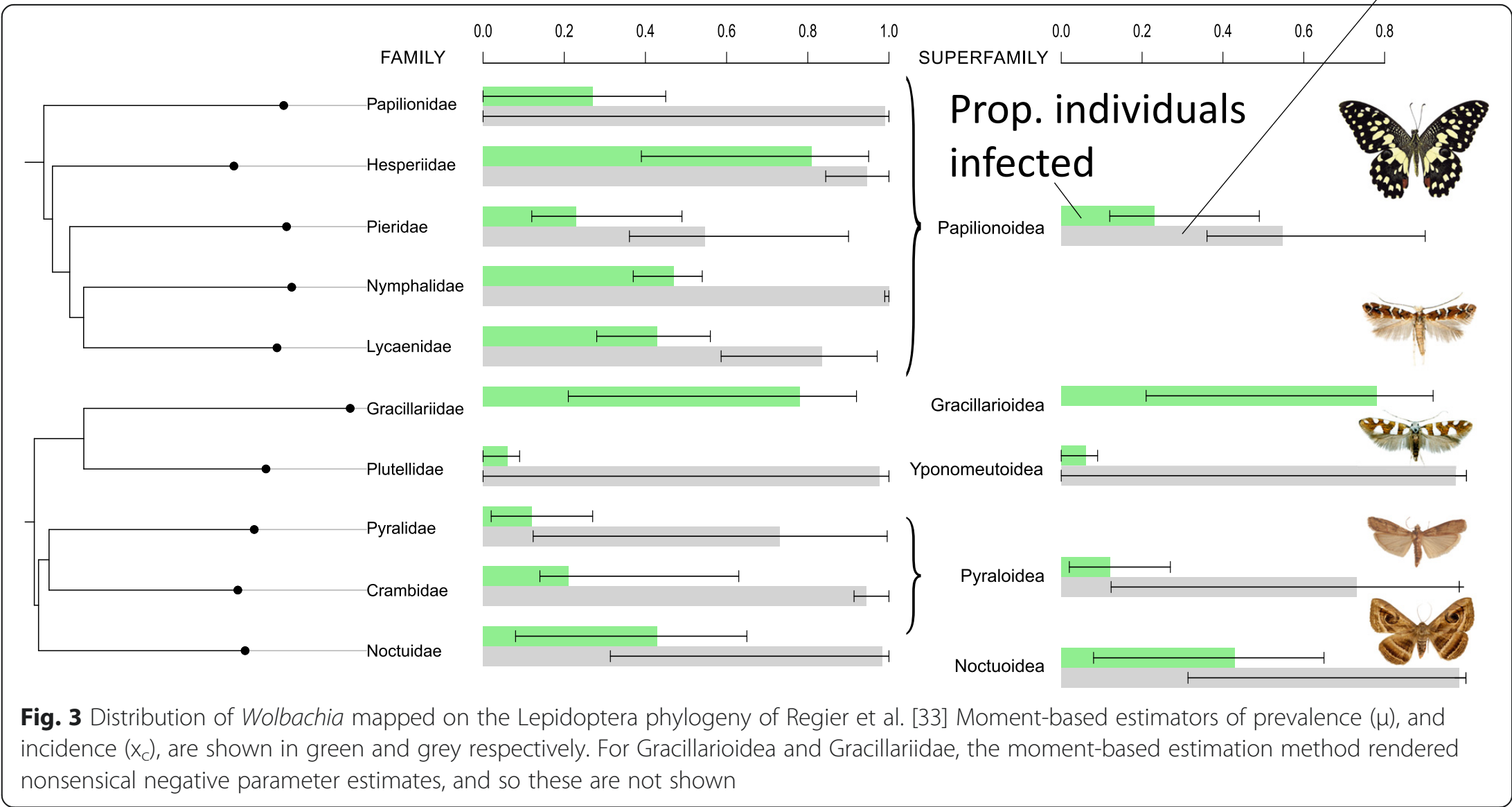
# Spread of a suppressor gene reveals another *Wolbachia* trick: cytoplasmic incompatibility



Feminization of genetic males can also occur!

# How common is *Wolbachia* in Lepidoptera?

Prop. species infected

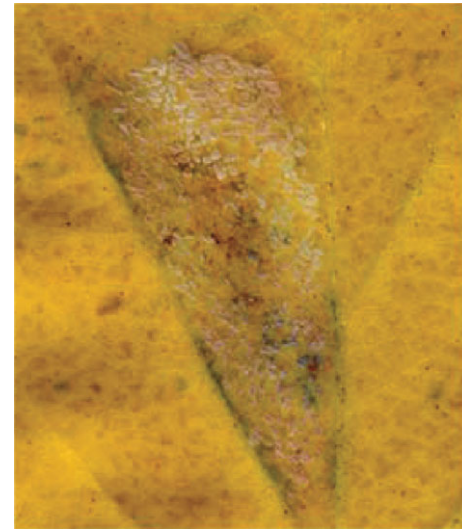


**Fig. 3** Distribution of *Wolbachia* mapped on the Lepidoptera phylogeny of Regier et al. [33] Moment-based estimators of prevalence ( $\mu$ ), and incidence ( $x_c$ ), are shown in green and grey respectively. For Gracillarioidea and Gracillariidae, the moment-based estimation method rendered nonsensical negative parameter estimates, and so these are not shown

# Is *Wolbachia* always a parasite?

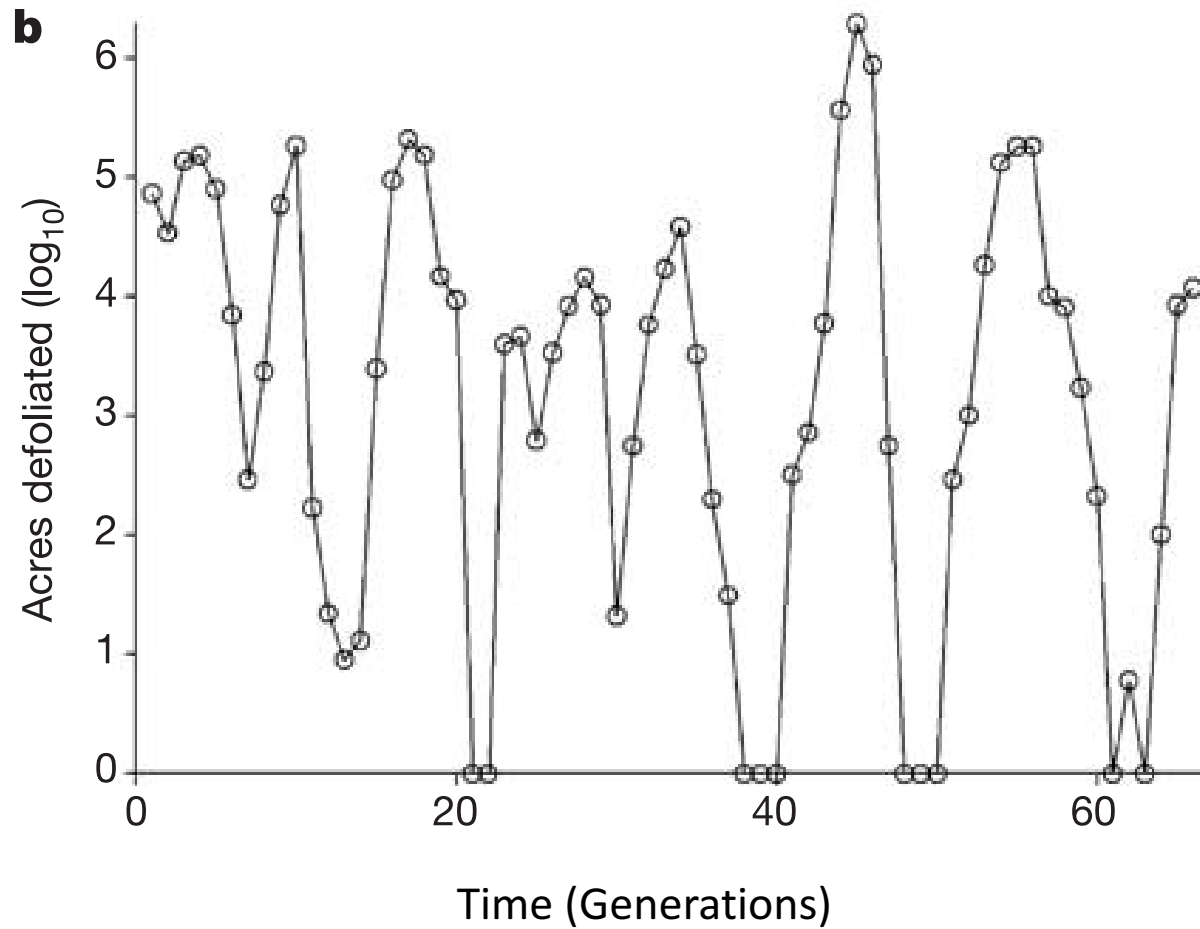


Spotted tentiform leafminer  
*Phyllonorycter blancardella* (Gracillariidae)



Kaiser et al. Proc. B 2010

# Viral epizootics cause gypsy moth population cycles



# Behavioral manipulation

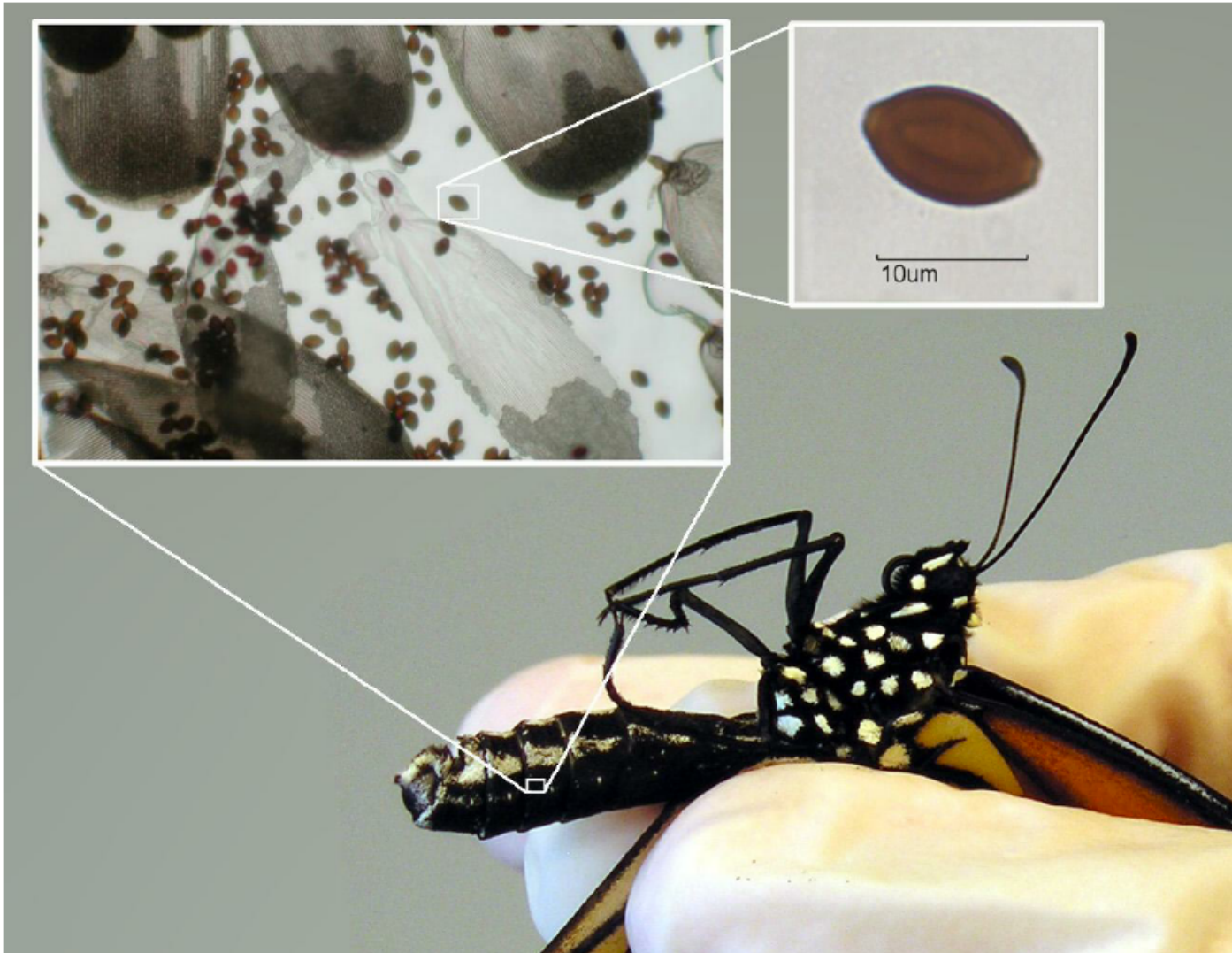
“Tree top disease” known for >100 years

Mechanism:

- Larvae normally crawl down the tree to molt
- Molting regulated by the hormone 20E
- *Lymantria dispar* nucleopolyhedrovirus encodes an enzyme that inactivates 20E, disrupting the molting cycle
- Infected larvae remain in the canopy, where they liquefy and “rain” viruses below

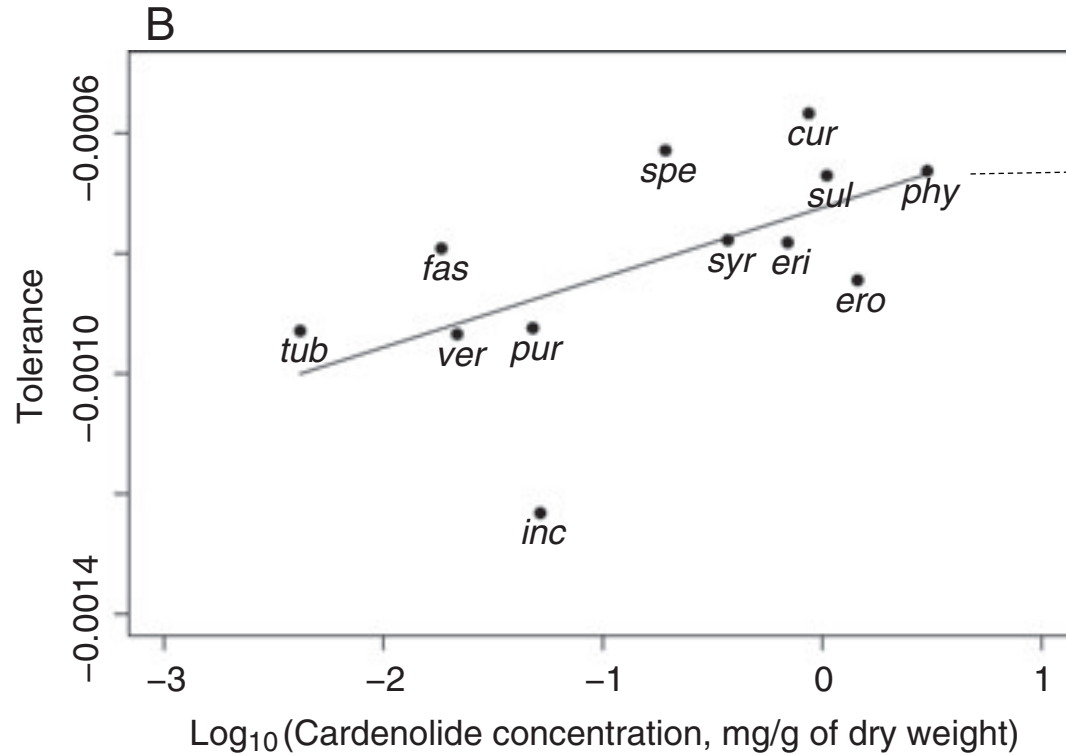


# *Ophryocystis elektroscirrha* and monarch butterflies



- Infects >70% of non-migratory monarchs in S. Florida
- Transmitted vertically (eggs) and horizontally (contaminated foliage)
- Reduces survival and adult size, mating success and lifespan

# The parasite is vulnerable to cardenolides



*A. physocarpa*

Infected females oviposit on high-cardenolide milkweeds

But these are worse for larval growth!

# *Ophiocordyceps* fungi and ghost moth caterpillars in the Himalayas



*Thitarodes* sp.



*Corallorhiza sinensis* (トウチュウカノウ)

Cooperation: Y. Kaitzu

Photo: F. Ihsa





Aloha Medicinals Inc 2010



Worth \$3,000 – \$15,000 per kg!



Aphrodisiac, boosts liver and kidney function, athletic performance... (supposedly)

MUSHROOM WISDOM

# Super Cordyceps

## Enduring through time

MUSHROOM WISDOM

冬蟲夏草

Cordyceps (*Cordyceps sinensis*) is a special mushroom that can only be found in an area 12,000 feet above sea level in southwest China and Nepal. Well-known for stamina and endurance, this mushroom is also known to support healthy sexual function as well as nourishment of lungs and kidneys\*.

**Modern Science Confirms Ancient Mushroom Wisdom**

Throughout Asia, mushrooms are used to maintain health, preserve youth, and increase longevity. Maitake Products, Inc., a pioneer in mushroom based dietary supplements, proudly introduces MUSHROOM WISDOM, a line of these valuable mushrooms in a vegetarian caplet. These supplements honor the wisdom of both SCIENCE AND TRADITION.

MUSHROOM WISDOM

Super Cordyceps

冬蟲夏草

WITH **ID fraction**

120 VEGETABLE TABLETS

Shiitake

Turkey Tail

Reishi

Lion's Mane

Tremella

Reishi Agaricus

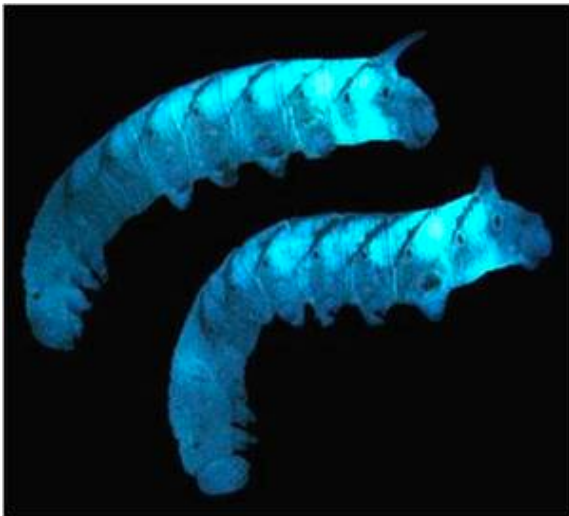
Cordyceps



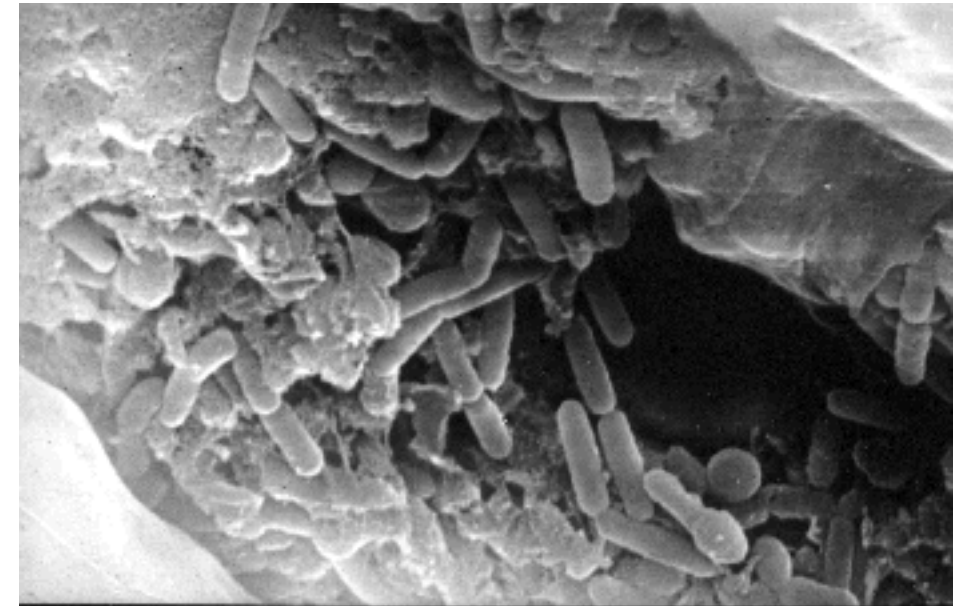
# Caterpillar-attacking nematodes



1. Nematodes find and enter a caterpillar, then vomit or defecate symbiotic bacteria
2. Bacteria invade and kill the caterpillar
3. Nematode eats the bacteria and reproduce in the cadaver
4. The caterpillar turns tan/brown and floppy (steinernematid infection), or turns red, glows in the dark, and smells (heterorhabditid infection)



“Angels’ Glow”



# Themes

1) Microbes sometimes explain puzzling phenomena, like ...

- Weird sex ratios
- Population cycles
- Oviposition preferences and other behaviors
- Caterpillar melting, glowing, and smells

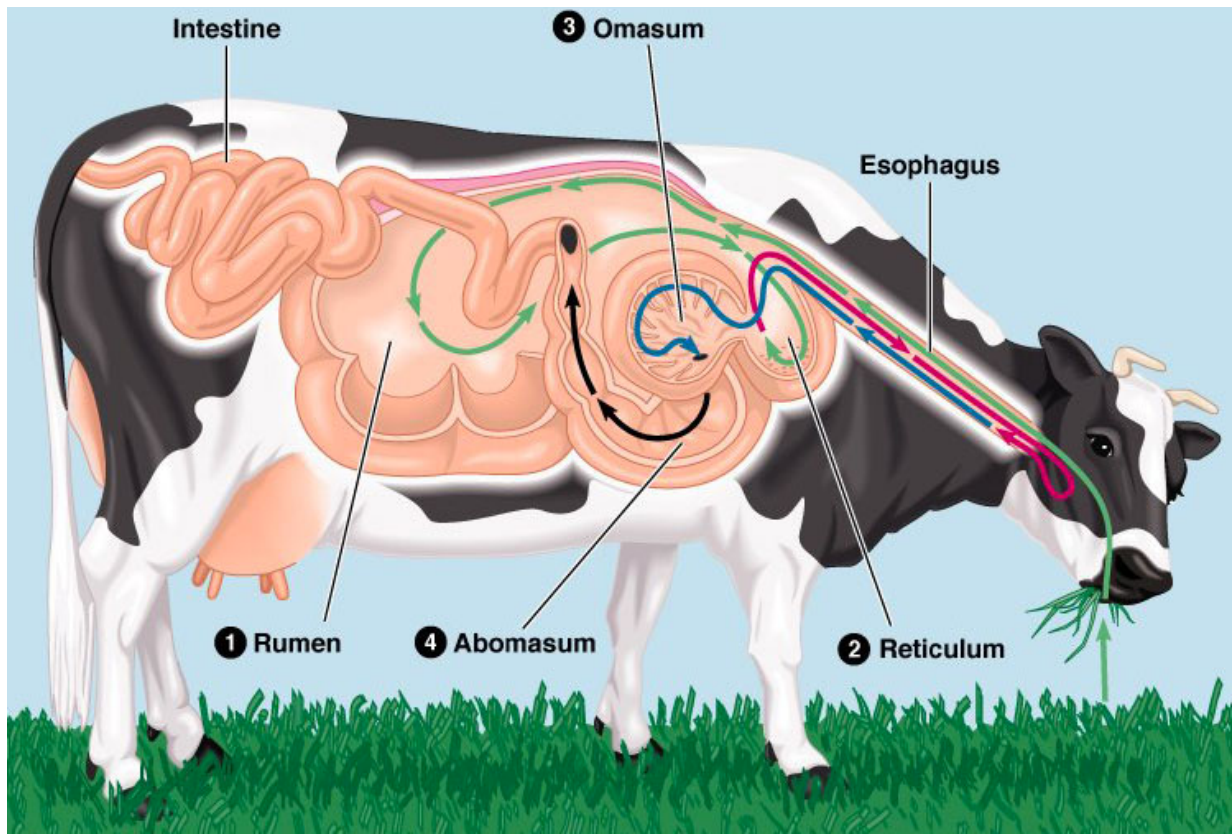
2) Lep parasites and pathogens are diverse and interesting!



# Do caterpillars have mutualistic gut microbes?

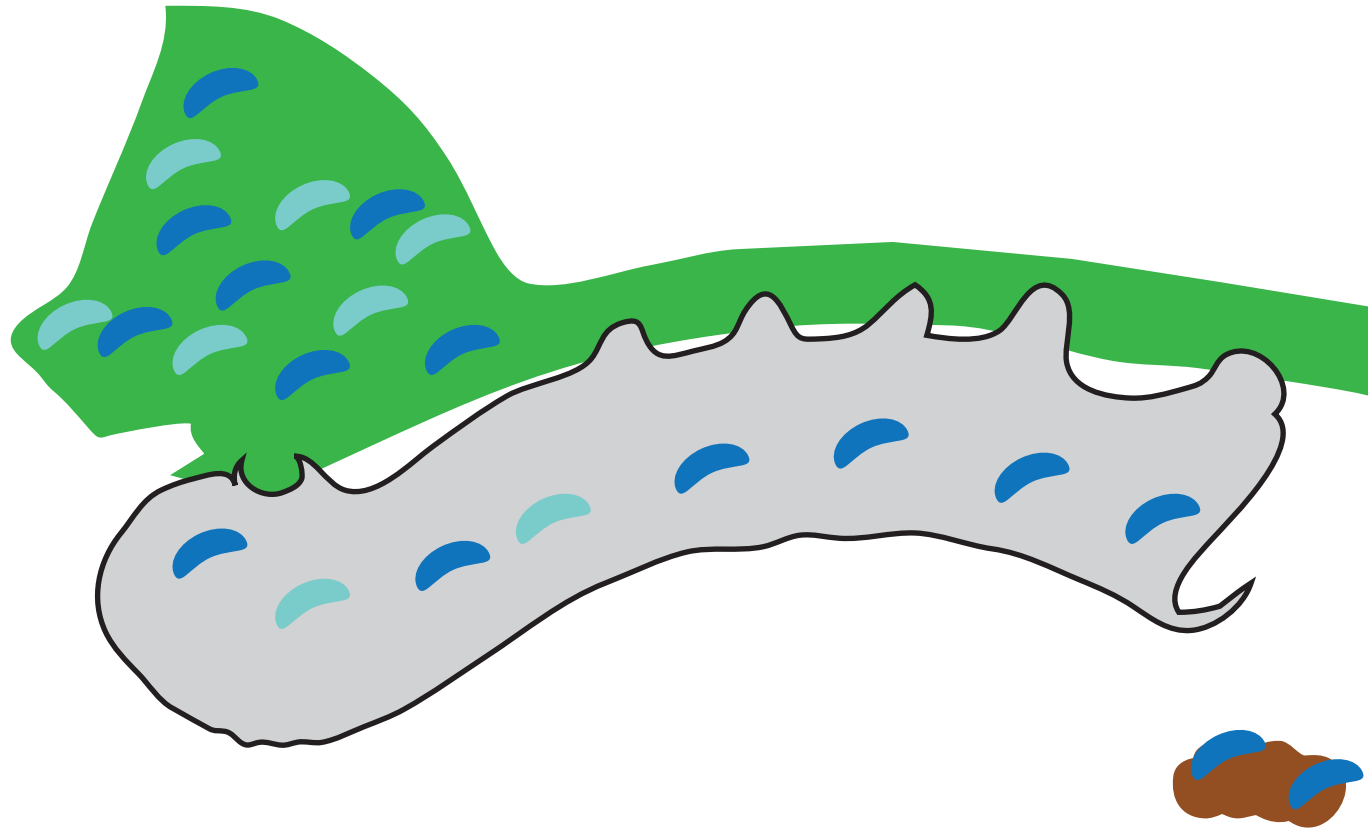
In 1911, Portier suggested that silkworms may benefit from the digestive activity of microorganisms ingested with mulberry leaves.

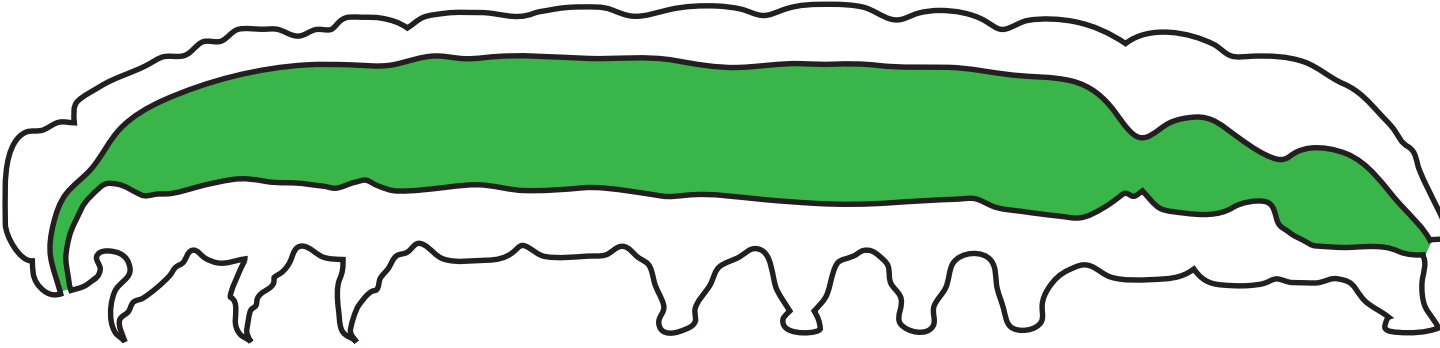
“...a group in which no symbiont-bearers have been discovered... indeed, even extreme lignivorous forms like *Cossus* have not learned to improve their position by acquiring symbionts.” – Buchner, 1953



<http://beawellgrassfedbeef.com/>  
Charis Tsevis Science (2015)

The caterpillar gut microbiome: a low abundance of transient “tourists” from leaves





- High pH, simple gut structure, and fast transit time prevent growth
- Can digest and detoxify plant material using their own enzymes



*Appel, Insect-Plant Interactions (1994)*  
Image modified from Snodgrass (1961)

# Might be a different story in (feeding) adults!



FIG. 1.—The celery caterpillar and butterfly, *Papilio polyxenes anterior* Stoll.

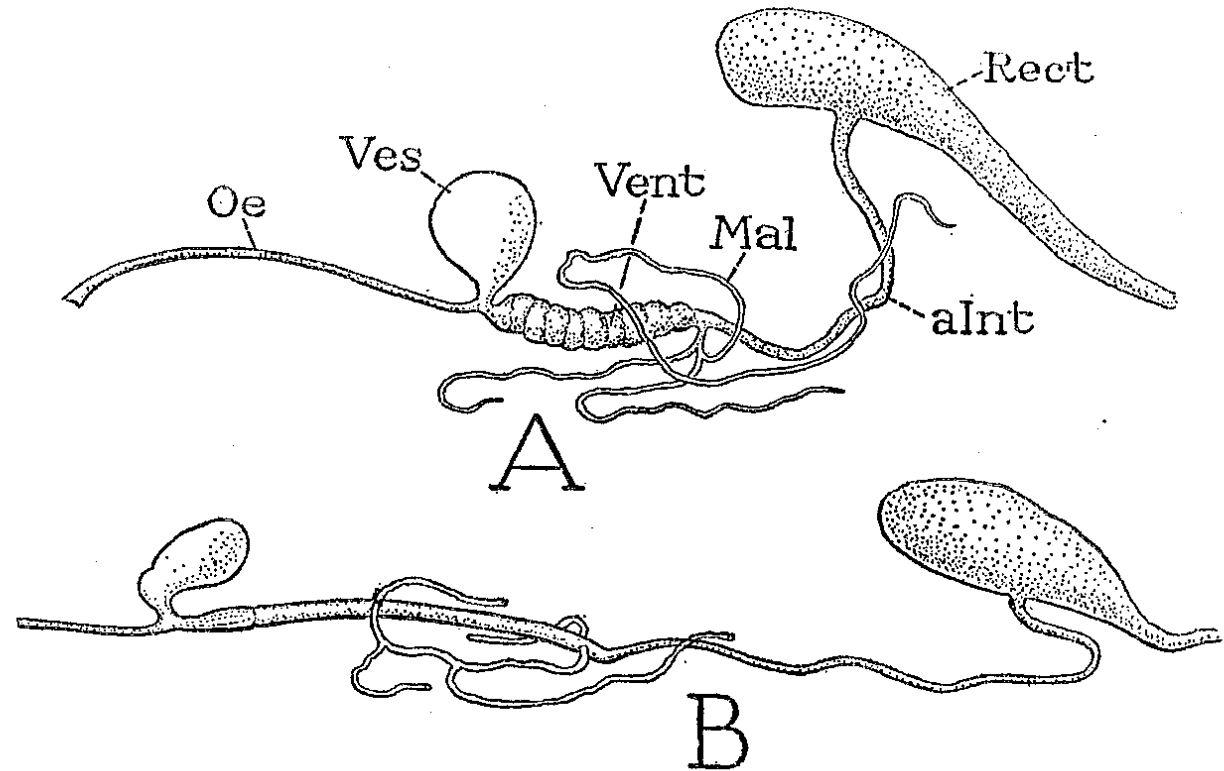


FIG. 4.—Alimentary canal of adult moths.

A, *Malacosoma americanum*. B, *Sanninoidea exitiosa*.  
aInt, anterior intestine; Mal, Malpighian tubules (not shown full length);  
Oe, oesophagus; Rect, rectum; Vent, ventriculus; Ves, oesophageal vesicle.